

In Situ Observations of Sediment Resuspension in a Non-Depositional Region of Southern Lake Michigan: A Comparison of Spring and Fall Events

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Abstract: Previous observations of near-bottom conditions and sediment resuspension in Lake Michigan have concentrated on areas of high sediment deposition in the southeastern part of the lake (Lesht and Hawley, 1987, Hawley and Lesht, 1995) and on Indiana Shoals in the southwestern part (Lesht, 1989). No previous observations have been made in the western areas of the lake adjacent to the Wisconsin bluffs, primarily because these waters were considered to be non-depositional and thus limited in the amount of resuspendible sediment available for transport. During 1998, the first EEGLE field year, we used an instrumented tripod to make measurements intended to test the hypothesis that the apparently recurrent winter-spring resuspension event (misnamed "plume") includes new material eroded from the Wisconsin near-shore. The results of these observations show that the local sediment, sandy cohesive clay, is indeed resuspended in response to the combined action of currents and surface waves. Net horizontal sediment flux in April 1998 was almost directly parallel to the shore and toward the south. In November 1998, however, the net horizontal sediment flux was onshore, perhaps representing the temporary storage of a more easily resuspendible pool of sediment. During 1999, the tripod was deployed in the high deposition region just off of Benton Harbor. The first deployment (2/25 to 4/19) failed because of a flooded pressure case. The second deployment (4/20 to 6/1) was successful and the data are being analyzed. The tripod was deployed again on October 15 and will be retrieved during the week of December 7.

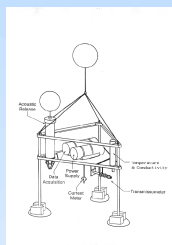
Objectives: Tripod observations are intended to address questions related to the physical response of the bottom sediments.

The two major goals are (1) to establish local threshold criterion of initiation of sediment resuspension, and (2) to measure the magnitude and direction of the horizontal near-bottom sediment flux during the formation, duration, and dissipation of the nearshore "plume." Questions to be answered include:

- How does the near-bottom sediment flux depend on the current forcing? Can we determine a consistent set of threshold and entrainment rate values for use in simple sediment transport models?
- Is the near-bottom horizontal sediment flux consistent with our conceptual model of sediment transport within the "plume?"
- What is the relative magnitude of sediment transport occurring during summer and fall resuspension events compared to the spring "plume" events?

Methods: The Argonne tripod (Fig. 1) is configured to gather basic information about the relationship between near-bottom flow and sediment transport. The measurements include horizontal current velocity (Marsh-McBirney 2-axis electromagnetic current meter), suspended sediment concentration (Seatech transmissometers), surface wave height and period (Paroscientific pressure sensor), water temperature, and tripod orientation. A digital time-lapse camera system was added for the October 1999 deployment. All the sensors with the exception of the pressure sensor are sampled at 4 Hz in burst mode for five minutes every half hour. The pressure sensor is sampled for an additional two minutes to establish the absolute water depth to which surface waves are referenced. Data statistics, including the burst mean, standard deviation, minimum, and maximum are recorded. We also record the covariance between the horizontal velocity components and wave pressure. The system endurance of about 60 days is limited by power.

Figure 1. The Argonne tripod basic configuration. One transmissometer is usually positioned approximately 100 cm above the bottom; another may be installed higher in the water column or elsewhere on the tripod. The current meter is approximately 75 cm above the bottom. Two temperature probes and the pressure sensor are located on the legs.



Deployment Strategy and Summary: We intend to sample both spatial variation by deploying the tripod in three different plume zones (Fig. 2): the Wisconsin bluffs (1998), the Michigan convergence area (1999), and the Illinois-Indiana border. We also intend to sample seasonal differences by keeping the tripod in the water as much as possible during the year, doing at least a spring, summer, and fall deployment.

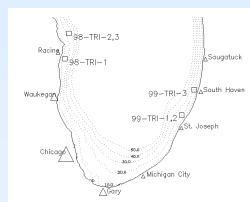
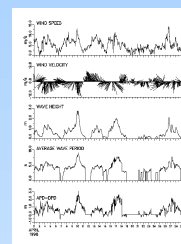


Figure 2. Tripod deployment locations in 1998 and 1999.

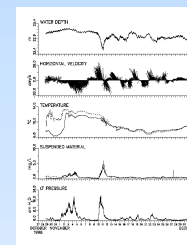
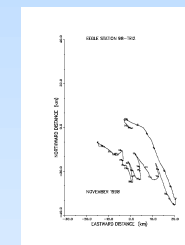
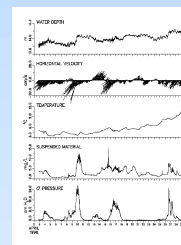
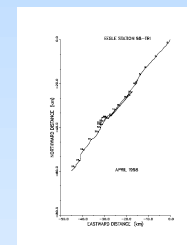
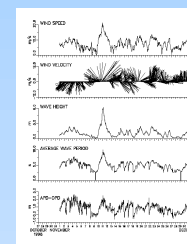
98-TRI-1 : 4/2/98 through 4/30/98 (1393 samples)
 98-TRI-2 : 7/23/98 through 8/24/98 (1539 samples)
 98-TRI-3 : 10/28/98 through 12/1/98 (1632 samples)
 99-TRI-1 : 2/25/99 through 4/19/99 (no data)
 99-TRI-2 : 4/20/99 through 6/1/99 (2064 samples)
 99-TRI-3 : Deployed 10/15/99, retrieval planned 12/7/99.

Results: The data shown below provide a preliminary comparison of resuspension events that occurred in a non-depositional region during the spring and fall of 1998. The basic observations for each deployment are illustrated in a group of three figures. The first figure shows the meteorological conditions recorded at NDBO buoy 45007 during the deployment. The second figure shows the basic data recorded by the tripod. The third figure in each group is a progressive vector diagram showing the integrated water motion during the deployment.

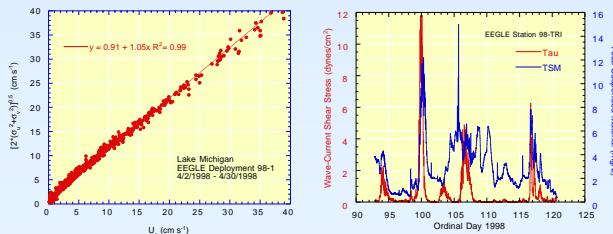
April 1998. Though not as dramatic as the event in March, it appears that the local sediments were resuspended four times. A large storm occurred on April 9-11 with wave heights at the buoy approaching 3 m. Net water movement was shore parallel to the south.



October 1998. A major storm occurred on November 9-12 resulting in waves approaching 9 m at the buoy and a drop in mean water depth. The local sediments were resuspended; near bottom concentrations exceeded 5 mg/L. Net water movement was onshore and slightly to the south.



Discussion: In both the spring and fall deployments the near-bottom velocity fluctuations were dominated by wave motion. The figure below (left), taken from the April 1998 deployment, compares the wave orbital velocity estimated from the current meter with the wave orbital velocity obtained by applying linear wave theory to the pressure sensor data. The results are almost identical for the October deployment (not shown) though the magnitude of the fluctuations is smaller in the fall because of the greater water depth. By plotting the TSM time series together with the estimated wave-current bottom shear stress (right figure below), we can estimate an approximate threshold stress for resuspension (~ 1 dyne/cm²) and also see that much of the variation in near-bottom sediment concentration is not associated with changes in bottom shear stress but is most probably related to advection of turbid water. Significant local resuspension occurs both in the spring and fall, even in the non-depositional areas.



References:

- Hawley, N. and B. M. Lesht, 1995. Does local resuspension maintain the benthic nepheloid layer in southeastern Lake Michigan? *J. Sed. Research*, A65(1):69-76.
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